RS
REGENERATION
General

June 7, 1920

FINAL REPORT

Project RS, F-1

Great Basin Experiment Station

District 4.

THE RELATION OF SOIL ACIDITY TO ARTIFICIAL REFORESTATION

By F. S. Baker, Forest Examiner.

RS
F-1

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Project.- The relation of soil acidity and alkalinity to artificial reforestation particularly with western yellow pine.

Object.- To determine the effect of soil acidity and alkalinity upon the germination of western yellow pine seed and growth of seedlings in comparison to Douglas fir and lodgepole pine.

Status.- While engaged in range revegetation studies in eastern Oregon, Sampson[1] found certain plant societies inhabiting soils which had an acid reaction while others had an alkaline. Among the plants most characteristic of the acid soils was western yellow pine, and Sampson concluded at that time that the soil acidity was necessary for the development of the species. The Pinus-Calamagrostis society in the Blue Mountains of Oregon is characterized by an acid soil of varying degree requiring from 2,000 to 11,000 pounds of lime per acre foot to neutralize the acidity.

On coming to the Manti Forest the absence of western yellow pine on the slopes which would seem to be favorable for this species was noted by Sampson together with the limy nature

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[1]Sampson, A. W. - "The Relation of Soil Acidity to Plant Societies." Proc. Soc. Am. For. V.7. pp. 51-57.

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of the soil and infrequent occurrence of plants indicating an acid reaction in the soil such as the members of the Ericaceae. In order to test out the idea that the alkalinity of the soil prohibits the growth of western yellow pine this project was initiated in 1913. The original plan called for the preparation of a sterile soil prepared from sandstone rock which would be watered with different concentrations of an acid solution obtained from decaying leaves. It was impossible, however, to carry out this plan of work and so another working plan was prepared and approved. Under this plan six different kinds of soil were secured from a number of sources, differing in degree of acidity.

The first was a lodgepole pine soil secured from near Big Springs, Idaho. This soil was derived from the basaltic rock of the Yellowstone Plateau and was decidedly acid requiring 2632 lbs. of lime per acre ft. for neutralization. It showed little humus color and may be classed as a very fine sandy loam, composed of volcanic ash, very fine sand and silt.

The second was manzanita soil obtained from the manzanita brush type in Ephraim Canyon. This soil was derived from a reddish brown sandstone rock, which was found outcropping in many places near where the soil samples were secured. This soil was taken from the top six inches only and contained certain amounts of organic matter and leaf debris. It was a very fine sandy loam and was slightly acid, requiring 610 lbs. of lime per acre foot for neutralization.

The third soil was named white fir soil, as it was found in a white fir type not far from the place where the previous sample was secured. It was a very fine light colored, sandy loam, neutral in reaction, having little humus or color from organic matter.

The fourth soil was a loamy fine sand from the natural western yellow pine type as found in the southeastern portion of the Manti National Forest in the area known as "The Pines" near the head of Link Canyon. This soil was very slightly alkaline.

The fifth soil, named aspen soil from the fact that it was secured from the upper four inches of soil in the aspen type near the Great Basin Experiment Station, was a mixture of aspen leaf mould with a little clay sub-soil. It was alkaline in reaction and very porous and rich.

The sixth soil was a clay of geological formation very highly calcareous, and decidedly alkaline in reaction. It was secured in a swamp near the Experiment Station nursery. The character and physical properties of the soil under consideration as used in this study are given in the following table:

THE SOILS

Source	Acidity Lime Req. Lbs. per A.ft.	Wilting Coefficient	Saturation	Per Cent Organic Matter
Idaho	2632	7.3	32.8	4.7
Manzanita	610	11.4	52.2	6.6
White fir	Neutral	5.6	25.5	3.9
Pines	Slightly Alkaline	3.3	27.4	6.5
Aspen	Alkaline	25.0	100.2	27.6
Clay	Decidedly Alkaline	14.1	61.2	8.2

The soil acidity was determined by means of the lime-water method by which small amounts of soil are treated with slowly increasing amounts of lime water until by repeated trial neutralization is found. The degree of alkalinity was simply estimated by the color secured on treatment phenophthalein. The wilting coefficient was determined by the indirect method in the Biophysical Laboratory, Bureau of Plant Industry. The content of organic matter was determined by incineration and subsequent treatment by carbonic acid in the case of the soils which contained lime in order to replace whatever carbon dioxide might have been lost in heating. These six soils were placed in boxes approximately 18 inches square and 18 inches deep, and in each of them

were planted 50 seeds each of western yellow pine and Douglas fir and 75 of lodgepole pine seed. The soils were all watered alike at frequent intervals. Of course, owing to the vastly different saturation per cent of these different soils the addition of equal amounts of water to each acted rather differently. Since, however, large amounts of water were used and drainage and percolation was rapid in these boxes, even the soils which had the highest saturation per cent were kept thoroughly moist during the period of germination. Germination took place first in the "Aspen" soil and in the "Pines" soil, being last in the clay. The rate of germination appears to be partly at least, determined by surface temperatures. At 4:30 P. M. on June 22, 1916, at the time when germination was going on rapidly, the following temperatures were observed in the soil at a depth of ¼":

Pines	71.5°	Manzanita	68°
Idaho	71.0°	Aspen	68°
White fir	68.0°	Clay	62°

At the end of the first year when growing season was finished a count was made of all seedlings alive in each of these soils with special attention to the western yellow pine. The results are shown in the following table:

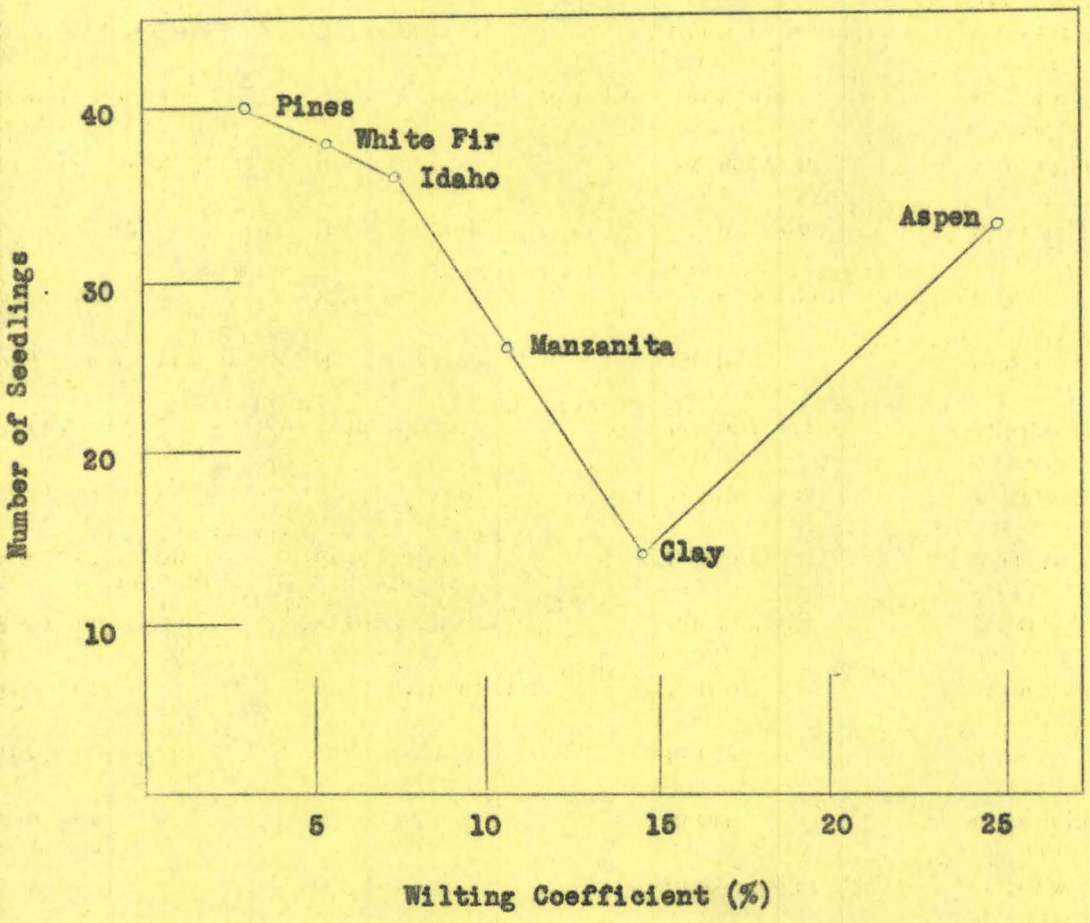
SEEDLINGS ALIVE AT END OF FIRST SEASON

OCTOBER 20, 1916

Soil	Western Yellow Pine	Lodgepole Pine	Douglas Fir
Idaho	36	2	24
Manzanita	26	13	7
White fir	38	23	6
Pines	40	40	24
Aspen	33	36	35
Clay	14	0	0

It is evident from this table that the survival of the western yellow pine seedlings was not determined by the degree of acidity, for the maximum was shown upon the pine soil which was slightly alkaline, while the manzanita which was slightly acid had next to the lowest number living. With the exception of the aspen soil the degree of success runs very much more nearly smooth according to the wilting coefficient of the different soils, the clay, with its high wilting coefficient, showing a very low per cent of survival, while the aspen, although its wilting coefficient was still higher than the clay, showed a per cent living which ranks well up with the best. The behavior of the soils immediately suggests that where the wilting coefficient is very high on account of a large admixture of humus, as is the case of the aspen soil, a favorable soil is indicated, whereas

RELATION OF NUMBER OF SEEDLINGS AT END OF
FIRST SEASON TO WILTING COEFFICIENT OF SOIL



where the wilting coefficient is high because the soil is heavy and clayey the effect is disastrous to the western yellow pine seedlings. The results indicate that the success of first year western yellow pine seedlings is largely dependent upon what is called in general the lightness of the soil. If a soil is porous and light whether on account of its content of sand, gravel, or other coarser material, or whether it is light on account of its high content of organic matter the result is about the same, although this lightness can not be readily expressed in a concrete way. Acidity is clearly not a limiting factor.

The behavior of the Douglas fir and lodgepole pine is not exactly the same as the western yellow pine. In general the tendency is for good success to be found on the lighter soils as is the case with western yellow pine, and the poorest success is found in the case of the calcareous clay. The best success, however, with lodgepole pine is found in the pines soil, while with the Douglas fir the best is in the aspen soil showing perhaps a slight preference of Douglas fir for the rich soil of an established forest in contrast to lodgepole pine which thrives on poorer soils or where the humus has been largely destroyed through burning. This is further borne out in the case of the white fir soil which has little humus, the lodgepole pine doing much better than Douglas fir. Further than this these species show little consistency. It may be remarked, however, that the lodgepole pine

seems to flourish on the soils where the Douglas fir does the poorest. It is especially remarkable that Douglas fir does excellently well upon the Idaho soil from the lodgepole pine type, whereas the lodgepole pine showed up extremely poorly, while on the white fir soil the Douglas fir did very poorly although lodgepole pine showed up excellently. There is not enough data at hand to offer any explanation regarding the behavior of these two species.

The spring following these counts the seedlings were again tallied and the result showed up very much the same as it did in the fall before, except that relatively greater death had taken place in the "pines" soil than in the "aspen." The greatest amount of death took place on the pines, white fir and Idaho soils, which are quite dissimilar as regards acidity, but which are all similar in having low wilting coefficients. After this examination one-half of the seedlings were dug up and measured. At the close of the second growing season the remaining half, now 2-0 seedlings, were also dug up and measured. The average development of the one-year old and two-year old seedlings of western yellow pine is shown in the following table:

Development of 2-year old Western Yellow Pine Seedlings in Different Soils

Source	Average length tops	Average length roots	Average weight	Basis No.
Idaho	3.25	7.31	.207	7
Manzanita	3.75	8.86	.356	12
White fir	2.51	7.72	.189	11
Pines	2.36	10.97	.177	18
Aspen	3.83	8.40	.460	12
Clay	2.53	7.78	.206	6

Development of 1-year old Western Yellow Pine Seedlings in Different Soils

Source	Average length		Average Weight	Basis No.
	Tops	Roots		
Idaho	1.63	5.96	.146	12
Manzanita	1.50	8.39	.155	9
White fir	1.50	6.04	.145	12
Pines	1.57	6.70	.146	8
Aspen	1.83	9.85	.275	13
Clay	1.60	6.60	.106	5

In these tables no relation is shown between development of tops or roots or total weight, to the degree of acidity in the soil. In fact the figures do not point consistently to any of

the factors secured as being the real determinant of growth. The impression given, however, is that the degree of development is caused by the general fertility of the soil rather than anything else since in both cases the weight is the greatest in the case of the plants which grew in the rich aspen soil, while the manzanita comes second. The results with Douglas fir and with lodgepole pine run very similarly and seem, like the western yellow pine, to be governed by fertility more than anything else. Root development is more uniform than the development of the tops and exclusive of the case of the pines soil, which on account of the fact that its depth was a little less than the others causing a spreading development of the roots on the bottom of the box, is extremely uniform. The development of the tops is much the greatest in the soils which show the best amounts of humus if the clay soil be excepted, and the total weight runs very much the same as the development of the tops.

It must be admitted that the data presented herewith is somewhat insufficient to base very definite conclusions upon, but it is believed that it shows beyond a doubt that the development of western yellow pine is conditioned more by the physical character (lightness) of the soil under consideration than any other factor in usual forest soils, and that acidity is not a limiting factor. Of course, when alkalinity or possible acidity rises to extreme points these factors may have considerable bearing upon

the growth of seedlings. While lightness of soil tends to favor the establishment of the young seedlings, their subsequent growth, except very heavy clays and other unfavorable soils, seems to be determined by the degree of fertility (organic content) of the soil. The experiment does not permit of any conclusions regarding the soil preferences of lodgepole pine and Douglas fir, but their development and growth also is very closely linked up with the fertility of the soil.

The conclusions reached regarding western yellow pine are in harmony with the observations of many experienced foresters. This species is found in many places toward the limits of its range upon soils of a decidedly sandy texture. Under the optimum climatic conditions existing in the middle of its range soil preferences are naturally much less marked, and in Arizona and New Mexico where mid-summer rains are heavy the species may be found flourishing on heavy soils. Toward the climatic limits, however, the preference for light soils is marked. Just how this soil factor acts is not clear. It is usually explained on the basis of soil moisture relations. The sandy soils tend to dry out more slowly and the moisture is supposed to be capable of more rapid movement toward the rootlets. In these experiments, the seedlings were very frequently watered and it would seem unlikely that these factors could become active until the soil moisture approaches the wilting coefficient; nevertheless, the differences are marked

and seem to indicate a preference of western yellow pine for light soils per se, regardless of moisture content.

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/s/
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